AMENDMENT HISTORY

The result matching section 60 calculates a similarity $D_i = D(S_{0j}, S_{ij})$ between the matching result S_{0j} and the matching result S_{ij} of each of the reference images in the reference image matching result storage section 50, and extracts reference images in the descending order of the similarity D_i of the matching result (step 103). The result of the extraction becomes, for example, as shown in FIG. 8. As reference images having a high possibility of being an image of the same object as the input image, R_1, R_5 and R_2 are obtained in the cited order. Finally, the reference images having high similarities are displayed (step 104).

As the calculation method of the similarity $D_i(S_{0j}, S_{ij})$ of the matching result, normalized correlation, rank_correlation, or the like can be used. The rank correlation is correlation of candidate precedence of the matching result. Denoting the candidate precedence of the matching result S_{0j} of the input image by A_{0j}, it follows that $A_{0,2} = 1$, A[redacted] = 2 and $A_{0,3} = 3$ in the case of the matching result shown in FIG. 7. Denoting candidate precedence of the matching result S_{ij} of each of the reference images by A_{ij}, for example, the Spearman's rank correlation can be obtained according to the expression $1 - 6\Sigma_j(A_{0j}-A_{ij})^2/\{N(N^2-1)\}$.

In the similarity calculation, the similarities may be calculated after conducting variable conversion on the variables (such as S_{0j}, S_{ij} and A_{0j}, A_{ij}). The similarities may be calculated by weighting variables with weights $g(A_{0j}, A_{ij})$ based on the candidate precedence A_{0j} and/or A_{ij}. For example, specific gravities of high precedence candidates become great by setting $g(A_{0j}, A_{ij}) = 1/(A_{0j}+A_{ij})$ and replacing the similarities S_{0j} and S_{ij} respectively by $S_{0j}/(A_{0j}+A_{ij})$ and $S_{ij}/(A_{0j}+A_{ij})$. The similarities may be calculated with low precedence candidates excluded.

In the same way as the operation of the first embodiment, representative three-dimensional object models C_j ($j = 1, 2, \dots, N$) as shown in FIG. 3 are stored in the representative three-dimensional object model storage section 20. Reference images R_i ($i = 1, 2, \dots, M$) respectively of the objects as shown in FIG. 4 are stored in the reference image storage section 70. A result (similarity) S_{ij} of matching of each of the reference images R_i with the representative three-dimensional object model C_j as shown in FIG. 5 is stored in the reference image matching result storage section 50.

In addition, M reference three-dimensional object models Bi ($i = 1, 2, \dots, M$) associated with the reference image R_i are previously stored in the reference three-dimensional object model storage section 21 as shown in FIG. 18.

It is supposed that an input image $I(u, v)$ as shown in FIG. 6 is obtained by the image input section 10 at the time of matching of the input image (step 100 in FIG. [redacted]). According to the same processing as the operation in the first embodiment, R_1, R_5 and R_2 are obtained in the cited order as reference images having a high possibility of being an image of the same object as the input image as shown in FIG. 8 by the image generation section 30, the image matching section 40, [redacted] and the result matching section 60 (steps 101, 102 and 103).

With respect to, for example, the reference images R_1, R_5 and R_2 which are three high precedence candidates in the matching result obtained from the result matching section 60, the second image generation section 31 acquires associated reference three-dimensional object models B_1, B_5 and B_2 from the reference three-dimensional object model storage section 21, and generates comparison images $H_{jk}(u, v)$ ($j = 1, 5, 2$, $k = 1, \dots, L$) which are close in input condition such as the pose and illumination to the input image

obtained from the image input section 10 (step 111). The generation of the comparison images $H_{jk}(u, v)$ is conducted by using a method similar to the step [redacted]. In other words, the second image generation section 31 generates L comparison images $H_{jk}(u, v)$ ($j = 1, 5, 2$, $k = 1, \ldots, L$) which are close in input condition such as the pose and illumination to the input image, with respect to the reference three-dimensional object models B_j ($j = 1, 5, 2$) in the reference three-dimensional object model storage section 21. The second image matching section 41 finds a similarity $S(I, H_{jk})$ between the input image $I(u, v)$ and each comparison image $H_{jk}(u, v)$, and finds a maximum similarity $S_{0j} = \max_k S(I, H_{jk})$ every model (step 112).

The matching results become, for example, as shown in FIG. 19. If S[redacted]>S[redacted]>S[redacted], then R_5, R_1 and R_2 are obtained in the cited order as reference images having a high possibility of being an image of the same object as the input image. Finally, the reference images having high similarities are displayed (step 104).

An image matching system according to a fourth embodiment of the present invention will now be described in detail with reference to FIGS. 20 to 22.

With reference to FIG. 20, an image matching system according to the fourth embodiment of the present invention includes an image input section 10, an image generation section 30, an image matching section 40, a result matching section 60, a second image generation section 31, a second image matching section 41, a result display section 80, a reference image storage section 70, a reference image registration section 75, a representative three-dimensional object model storage section 20, a three-dimensional object model registration section 25, a reference image matching result storage section 50, a reference image matching result

in FIG. 3 are stored in the representative three-dimensional object model storage section 20. Reference images R_i ($i = 1, 2, \ldots, M$) respectively of the objects as shown in FIG. 4 are stored in the reference image storage section 70. A result (similarity) S_{ij} of matching of each reference image R_i with the representative three-dimensional object model C_j as shown in FIG. 5 is stored in the reference image matching result storage section 50.

In addition, M reference three-dimensional object models Bi ($i = 1, 2, \ldots, M$) associated with the reference image R_i are previously stored in the reference three-dimensional object model storage section 21 by the processing conducted at the time of reference image registration, as shown in FIG. 18.

It is supposed that an input image $I(u, v)$ as shown in FIG. 6 is obtained by the image input section 10 at the time of matching of the input image (step 100 in FIG. [redacted]). According to the same processing as the operation in the first embodiment, R_1, R_5 and R_2 are obtained in the cited order as reference images having a high possibility of being an image of the same object as the input image as shown in FIG. 8 by the image generation section 30, the image matching section 40, and the result matching section 60 (steps 101, 102 and 103).

With respect to, for example, the reference images R_1, R_5 and R_2 which are three high precedence candidates in the matching result obtained from the result matching section 60, the second image generation section 31 acquires associated reference three-dimensional object models B_1, B_5 and B_2 from the reference three-dimensional object model storage section 21, and generates comparison images $H_{jk}(u, v)$ ($j = 1, 5, 2$, $k = 1, \ldots, L$) which are close in input condition such as the pose and illumination to the input image obtained from the image input section 10 (step 111). The second image

the pose condition) the same on the basis of each reference three-dimensional object model associated with the reference image obtained from the reference three-dimensional object model storage section 21. Thus, the image conversion section 36 generates partial images. The image conversion section 36 is similar to the image conversion section 35 in the second conventional technique shown in FIG. 28.

The partial image matching section 45 conducts comparison on the partial images of the converted input image and reference image obtained from the image conversion section 36, and calculates the similarity. The similarity calculation is conducted in the same way as the step [redacted].

General operation of the fifth embodiment will now be described in detail with reference to FIG. 23 and a flow chart shown in FIG. 24.

At the time of input image matching, steps 100, 101, 102 and 103 shown in FIG. 24 are the same as the operation conducted in the first embodiment shown in FIG. 2. With respect to a reference image of a high precedence candidate in the matching result obtained from the result obtained from the result matching section 60, the image conversion section 36 converts the input image and/or the reference image so as to make the input condition (such as the pose condition) the same on the basis of each reference three-dimensional object model associated with the reference image obtained from the reference three-dimensional object model storage section 21. Thus, the image conversion section 36 generates partial images (step 121).

The partial image matching section 45 conducts comparison on the partial images of the converted input image and reference image obtained from the image conversion section 36, and calculates the similarity (step

an image matching step of calculating a similarity between the input image and each of the comparison images generated at the image generation [redacted], selecting a maximum similarity with respect to comparison images associated with each representative three-dimensional object model, and regarding the maximum similarity as a similarity between the input image and the representative three-dimensional object model;

a step of storing the reference images of objects in a reference image storage section;

a step of storing similarities between the reference images stored in the reference image storage section and representative three-dimensional object models stored in the representative three-dimensional object model storage section, in a reference image matching result storage section;

a result matching step of extracting the reference image similar to the input image on the basis of similarities between the input image and the representative three-dimensional object models calculated at the image matching step and similarities between the reference images and the representative three-dimensional object models stored in the reference image matching result storage section;

a step of storing reference three-dimensional object models associated with the reference images stored in the reference image storage section, in a reference three-dimensional object model storage section;

an image conversion step of obtaining reference three-dimensional object models associated with reference images extracted at the result matching step, from the reference three-dimensional object model storage section, squaring an input condition of the input image with that of the reference image extracted at the result matching step by converting the input image and/or the reference image extracted at the result matching

result update step, for generating the reference three-dimensional object model associated with the reference image by combining the representative three-dimensional object models stored in the representative three-dimensional object model storage section on the basis of the similarity, and registering the generated reference three-dimensional object model in the reference three-dimensional object model storage section.

35. The image matching method according to claim 34, wherein

at the three-dimensional object model generation step, a reference three-dimensional object model associated with each reference image is generated by combining representative three-dimensional object models stored in the representative three-dimensional object model storage section every partial region, on the basis of similarities obtained [redacted] between reference images stored in the reference image storage section and representative three-dimensional object models stored in the representative three-dimensional object model storage section, and the generated reference three-dimensional object model is registered in the reference three-dimensional object model storage section.

36. The image matching method according to claim 33, wherein

at the image matching step, a similarity between the input image and a representative three-dimensional object model is calculated every partial region,

the reference image matching result storage section stores similarities between the reference images stored in the reference image storage section and representative three-dimensional object models stored in the representative three-dimensional object model storage section, every partial region, and

model associated with the reference image by combining the representative three-dimensional object models stored in the representative three-dimensional object model storage section on the basis of the similarity, and registering the generated reference three-dimensional object model in the reference three-dimensional object model storage section.

54. The image matching program according to claim 53, wherein

at the three-dimensional object model generation step, a reference three-dimensional object model associated with each reference image is generated by combining representative three-dimensional object models stored in the representative three-dimensional object model storage section every partial region, on the basis of similarities obtained every partial region between reference images stored in the reference image storage section and representative three-dimensional object models stored in the representative three-dimensional object model storage section, and the generated reference three-dimensional object model is registered in the reference three-dimensional object model storage section.

55. The image matching program according to claim 52, wherein

at the image matching [redacted], a similarity between the input image and a representative three-dimensional object model is calculated every partial region,

the reference image matching result storage section stores similarities between the reference images stored in the reference image storage section and representative three-dimensional object models stored in the representative three-dimensional object model storage section, every partial region, and

at the result matching [redacted], the reference image similar to the input image is extracted on the basis of similarities between the input

FIG.12

REFERENCE IMAGE NUMBER	OBJECT MODEL NUMBER AND SIMILARITY
R_1	$C\cancel{R}_{51}$: 0.97
R_2	$C\cancel{R}_{51}$: 0.92
R_3	$C\cancel{R}_{51}$: 0.83
·	
·	
·	

FIG.13

50 REFERENCE IMAGE MATCHING RESULT STORAGE SECTION

REFERENCE IMAGE NUMBER	OBJECT MODEL NUMBER AND SIMILARITY			
	FIRST PLACE	SECOND PLACE	THIRD PLACE	· · ·
R_1	C_2 : 0.98	C_{51} : 0.97	C_5 : 0.96	
R_2	C_3 : 0.95	C_2 : 0.93	C_{51} : 0.92	
R_3	C_1 : 0.97	C_9 : 0.96	C_8 : 0.93	
·				
·				

FIG.14

REFERENCE IMAGE NUMBER	OBJECT MODEL NUMBER AND SIMILARITY			
	FIRST PLACE	SECOND PLACE	THIRD PLACE	· · ·
R_{101}	C_2 : 0.99	C_6 : 0.98	C_3 : 0.96	